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Art. XIII.—*Modern Improvements in Rock Section Cutting Apparatus.*

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(With Plates XIV.-XVII.).

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1.—Introductory and General.

The cutting of Rock sections for class use and research work occupied a considerable proportion of the writer's time, and also entailed much labour, until a little over two years ago, when an effort was made to improve upon the apparatus at that time available for rock slicing. To attain this end, it was deemed best to build an entirely new machine, which should be electrically driven and embody all that was best in the earlier forms of lapidary's machine, while introducing such improvements and modifications as a considerable experience of rock slicing had shown would be advantageous.

At the outset, I may say that where only a *few* sections are likely to be required, a machine of any kind is not an absolute necessity. Given reasonably thin chips or flakes, such as can readily be obtained with a hammer, also plenty of time and energy, coupled with a fair amount of skill, and thin sections, in every way comparable with those made with the aid of mechanical devices, can be obtained. Hand work of this character is, however, both slow and laborious, and the preparation of any considerable number of sections becomes a serious undertaking.

In the early days of rock section making, the professional lapidary was usually resorted to, when a number of sections were required. Naturally, the machine used by him was the one first adopted by the Geologist, who, either from choice or necessity, prepared his own sections. The ordinary lapidary's machine, though effective in his hands for his own particular work, is both crude and inconvenient for rock-section making.

A machine of this character was sent from London to the Melbourne University some 10 years ago. It was said to be a duplicate of one in use at the British Museum, and was then regarded as an up-to-date machine for rock slicing. I am unable to discover that this machine possesses any material advantage over the older types of similar apparatus.

Many years ago the late Mr. Jordan devised a simple and fairly convenient machine,[1] worked by means of a treadle. This machine, unlike that used by the lapidary, leaves both hands free for other manipulations—which is a decided convenience. This type of machine has since been modified, and improved, in respect to details, more especially by German petrologists, whose energies, however, seem to have been chiefly directed to devising elaborate and ingenious clamps for holding and orientating the specimen to be cut. Nearly all the more important German firms who cater for geologists now provide machines designed for driving either by foot or motor power. Generally speaking also, German rock-slicing apparatus is distinctly in advance of that made by English and American firms.

My reasons for building a machine, when so many other types were available to choose from, were mainly as follows:—

A fairly long experience in the preparation of rock sections had served to bring out some of the weak points of at least three machines with which I had worked. Moreover, I had adopted a process of section making, differing somewhat from that ordinarily followed, which made it possible largely to substitute slicing with diamond powder for grinding with emery, without material increase in cost, and with a great economy of time.

One of the chief drawbacks pertaining to the machines of which I had had experience, was that, ordinarily, they were speeded to run at from 300 to 500 revolutions per minute.

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1 A plan and section of the Jordan machine may be found in Rutley's "Study of Rocks," p. 64, 4th ed., 1888.

The ordinary lapidary's machine is figured in Holtzapffel's "Mechanical Manipulation," vol. iii., 1894 ed.

with slicing and grinding discs of 8in. diameter and less. Both experience and experiment had satisfied me, that, given an accurately made motor-driven machine, slicing and grinding discs 10in. in diameter might safely be speeded up to 1000 revolutions per minute, with a proportionate increase in efficiency. This conclusion, the results obtained have fully sustained.

Again, all the machines of English design and make, so far as my experience of them goes, are only provided with one revolving spindle or mandrel, which is invariably made to pass through the centre of both slicing and grinding discs, thus greatly limiting the efficiency of the latter. The single spindle also entails frequent changes from slicer to grinder; and further changes of the grinding laps, according to the differing grades of abrasives used; two of which, at least are always required. These frequent changes, of course, involve a considerable loss of time.

A further important defect — and this applies to both English and German machines—is that they have a far too limited top or bench space, hence both slicer and grinder are inconveniently crowded together, seriously hampering freedom of movement in both slicing and grinding operations. This crowding together of rapidly moving parts is also nearly always associated with inadequate protection to bearings and screws, etc., against the intrusion of emery or carborundum, the presence of which even for a short time is very destructive as well as difficult to remove.

In the machine I have constructed—and to which I may now briefly refer I have endeavoured to fully provide against the several shortcomings I have named. The machine is speeded to run at close upon a thousand revolutions per minute. The slicing discs and grinding laps are 10in. in diameter. The latter are mounted like the face plate of a lathe; they run dead true, and have a clear surface for all operations. The laps and slicer are each separately mounted, with ample space for free movement, as well as with efficient guards, both with respect to the operator's clothes, the bearings and other moving parts: the necessity for such protection is obvious.

The motive power and running gear have both received careful consideration, so as to reduce noise and wear and tear to a minimum. Each grinder and the slicing discs are independently operated, and can be instantly thrown in or out of action by the mere push or pull of a conveniently placed handle. There are no idle running bands or belts; motion being communicated as required from a single overhead shaft by a specially designed clutch.

The net gain from these advantages, of which I give only the briefest outline, is that it has been made possible, as the result of actual trial, to slice a specimen suited for examination under the microscope—i.e., a section having an area of about one inch in diameter, and reduced to a thickness of less than .001 inch—the whole operation—slicing, grinding and mounting, occupying not more than 10 minutes—the specimen in question being a piece of granite. On no other machine, with which I am acquainted, is it possible to do this work within so short a time.

With regard to economy in working, the machine costs for motive power, running say 6 hours, not more than 6d. The cost for diamond powder, for slicing purposes—also deduced from actual trial—for a well charged disc, is not more than 1s. With this charge 95 slices, averaging 1in. in diameter and cut from about 20 different varieties of rock, ranging in hardness from granite to soft sandstone, were sliced without a re-charge of the disc.

Provision has been made, in addition to ordinary rock slicing, for cutting and grinding crystals to definite faces, and also for cutting and grinding parallel plates to a precise thickness.

More recently, a further modification has been made, adapting the machine to the cutting of serial sections, as, for example, in the case of a fossil imbedded in a piece of rock, etc. The method was first devised and described by Professor Sollas, of Oxford University, in the Transactions of the Royal Society of London for 1903. Professor Sollas obtained a special grant from the Royal Society for the construction of his machine, which was designed by the Reader of Mechanics—Mr. Jervis Smith, of Oxford University.

After reading Professor Sollas' description of this machine, I saw at once that, with no modification of the machine my paper describes, other than the addition of a graduated circle and index point, it would be possible to undertake exactly the same kind of work as that for which the Oxford machine had been exclusively designed, and, as I think, with greater facility and convenience; the parallel clamp, which swings radially over the grinding disc of my machine, being already provided with the requisite adjustments for securely holding specimens requiring special serial treatment. Plate XVII., Fig. 1, shows the relations and simplicity of this apparatus. The radial clamp, holding a glass plate, to which a specimen is cemented, is seen in position over the grinding lap, its relation to the latter being controlled and adjusted by means of the graduated head on the top of the pillar to the right of the lap. Fuller details of this appliance will be found in Section 2 and in the explanation of the plates. Considerable experience of grinding operations requiring not only precision but delicacy of touch and freedom of manipulation over the surface of a rapidly revolving disc, convinces me that the requisite conditions for precise work are not as fully provided for as they might be by the slow and rigid traverse of Professor Sollas' machine. Moreover, his grinding laps are very small, being only 4in. in diameter, and driven by hand. The working of such a machine cannot but be inconvenient, seeing that one of the operator's hands is fully occupied with driving the machine, leaving only one hand free for controlling the various adjustments of the machine screws, and for applying water and the necessary abrasives, etc. These operations, if the machine is to be efficiently worked, requires the unremitting attention of more than one hand. The fact that Professor Sollas is fully satisfied with the results he obtains does not, I think, preclude the propriety of pointing out that equally good results may be obtained from simpler and much less costly adjustments, applied to an existing apparatus.

I may say that in addition to the various processes just described, my machine is admirably suited to all polishing operations; the comparatively high speed at which it is run rendering it particularly effective for this class of work.

The completed apparatus has now been in use for more than two years, and as it has fully met expectations I venture to describe it with sufficient detail to enable others to benefit by my experience. As the method of rock slicing and section mounting are, in a measure, related and co-ordinated, it is necessary also to include a short account of the latter process.

2.—Structural Features of the New Machine.

A detailed description of all the working parts of the machine, with plans to scale, is beyond the scope of this paper. Fortunately they are not, I think, necessary, as with the aid of photographs (Plates XIV. to XVII.) showing all the essential features of the apparatus and descriptions of less obvious features, it should be possible for an intelligent mechanic to construct a similar machine.

At the outset it is necessary to point out that in the building of the apparatus, I was strictly limited as to position and space.

Dealing with the several portions of the machine in order: —*Plate XIV.*, which may be regarded as equivalent to a sectional or front view, shows all the principal features of the apparatus, which is built into a corner of the workroom; the lathe in the foreground has no connection with the rock slicer, beyond being driven by the same motor. The three guard trays have been removed from the top of the rock machine table, in order to show the position and relation of the slicing and grinding-lap spindles, and of the several supports for rock holders and clamps.

Plate XV. may be regarded as a photograph in plan—i.e., looking down upon the machine. It shows to better advantage the relation of the working parts in running order, other than the driving mechanism, which is situated at some height above the machine, and is shown in detail in Plate XVI.

Plate XVII. (Figs. 1 and 2) serves to show the special appliances for serial section cutttng, parallel grinding, and work with the goniometer.

Reverting to Plate XIV., it will be seen that the base of the machine is a strongly built wooden bench or table with dimensions as follows:—Length, 7 feet; width, 2 feet 4 inches;

height, 3 feet 2 inches. The table top, which is $1\frac{3}{4}$ inches thick, is supported on a strong, well-braced framework, which is screwed to the wall of the building so as to insure complete freedom from vibration. The details of the construction of the table may be readily made out from an inspection of Plates XIV. and XVI., except that a supporting beam for the three spindles, which runs from end to end of the table, 9 inches below its surface, cannot of course be seen.

3.—Details of the Principal Mechanical Parts.

These are described in order, from right to left, as they appear in Plate XV. First comes the vertical revolving spindle of the slicer. This is made of mild steel—as indeed are all the spindles—15 inches long, by $1\frac{1}{8}$ inches in diameter. It passes through an accurately bored, flanged collar 3 inches long, screwed to the surface of the table. The lower end of this spindle, as also those of the grinding lap, is coned and fits into a corresponding metal socket, provided with an oil recess and protecting collar, which is screwed to the longitudinal beam of the table frame. The top of the spindle is threaded and carries carefully fitted collars and flanges for clamping the slitting discs.

Somewhat to the right of and behind the spindle of the slicer, is a rod of steel 1 inch in diameter and 18 inches long. The lower part of this rod, which is of somewhat greater diameter than the upper part, is coarsely threaded for 6 inches of its length, and screws into a long nut or socket fitted to the table, thus forming an adjustable support for the various specimen clamps. The rod has 3 inches or more of motion by means of a screw, and a further range is obtained with the aid of lock nuts sliding on the spindle itself.

The larger specimen holder is of the usual parallel screw clamp type, and will hold specimens up to 5 inches in diameter. Several interchangeable clamps are used; one of these, to be seen in the photograph (Plate XV.) is adapted to hold thick pieces of plate glass $3\frac{1}{2}$ x $1\frac{1}{2}$ inches (length and breadth) to which the ordinary microslips are attached. In addition to its radial motion this carrier revolves axially, so that specimens to be sliced may be tilted at any convenient angle in relation to the slitting disc. This clamp also carries the goniometric crystal holder (shown in the front right corner of the tray) which permits of slicing or grinding in any desired direction. The device for maintaining a steady pressure or pull against the slicer comprises the usual cord, weights and pulleys, so placed as to be readily controlled.

Lubrication of the slicer is provided for by means of a drip-can and two pieces of sponge, one above and one below the disc held in position by a spring clamp.

Passing now to the grinding laps, of which there are two, seen in the centre of the table, it will be noted that they are screwed to the top of the spindles by means of a threaded boss below each plate. This mode of mounting allows the whole surface of the lap to be utilised, and is a convenience which has only to be once used to be appreciated. It not only allows the utmost freedom of movement, but also aids in the maintenance of a true surface on the lap for a long time. The spindles of the laps are somewhat shorter than that of the slicer, their length being 12 inches, so that the lap surface is about $3\frac{1}{2}$ inches above the table, which is a convenient height for most operators. The mounting of the spindles is the same throughout, and has already been described. Dust and grit are excluded from the bearings by means of a special close-fitting collar in each case.

It will be seen that each grinding spindle is accompanied by a pillar which supports a clamping device in which specimens or blocks of glass are held so as to swing radially across the laps. This permits of parallel grinding to a precise thickness or definite form, and though not necessary for ordinary rock slicing, it has, as already explained, a variety of uses where precision is required.

The lower portion of each rod is threaded, and screws into a long socket let into the surface of the table. It can thus be accurately raised and lowered during use, so as to maintain a steady and even pressure upon the lap. It is also adapted to carry the goniometer which fits the special holder shown in the centre tray, and, as already indicated, as every part of the machine is interchangeable if so required, a rapid transfer from one lap to another can be made. This correspondence between the several parts of the machine, and the facility of interchange which is thereby effected, results in the long run in a considerable saving of time.

The most effective laps, so far as my experience goes, are those of bronze containing a high percentage of copper, the aim being to secure a tough but not unduly hard lap. Pure copper laps would no doubt be better but they are difficult to cast and turn. Discs of lead and tin, and also of wood with felted surfaces are used in special cases and for polishing. A diameter of 10 inches is found to be convenient for most of these laps.

Tray-like shields, or mud guards are provided for each of the grinding laps as well as for the slicer. As will be seen, they are of square outline and conveniently large, the distance between the several spindles, 22 inches, permitting of this. The trays are made of stout galvanised iron 5 inches deep, and the upper edges are rounded and brass bound, forming clean and comfortable supports for the hands and arms of the operator. It should also be noticed that a space around each pillar or spindle is raised and carefully capped, so as to exclude dust and grit; this, in addition to the brass collars already noticed. The bearings of a machine running at a high speed, and upon which carborundum and other abrasives are to be freely used, cannot be too carefully protected from their intrusion: the life of the bearings is, in fact, directly proportional to the effective exclusion of the abrasives.

As already stated, the machine is motor driven, and as the method of connecting up is in some respects novel, I refer to it in some detail. An electrically driven one-horse-power motor serves to run the rock slicer, lathe, emery wheel and polisher, and has proved fully adequate for all requirements. As the motor runs at 1400 revolutions per minute, the main shafting, shown in Plate XVI., speeded down to about 300, a convenient speed for the driving wheels of both lathe and rock slicer. The usual method of gearing to a secondary shaft by means of belts and loose pulleys has been dispensed with, and a system of connecting directly to the main shaft adopted. This permits of any single portion of the section apparatus being run separately; the remaining cords and pulleys being stationary. This effects a saving of power, and reduces the wear and tear upon the machine and belts or cords. The slicer, and each grinder and the polisher, are hence directly connected to the principal shafting, which runs loosely through each driving pulley, when the latter are not engaged. These pulleys are thrown into action, each by its own clutch, which is operated by a loose coned sliding collar on the main shaft. The sliding cone is moved directly from the work table by means of a rod, to the lower end of which a lever handle bar is rigidly screwed in a convenient position. At the top of the rod is a forked lever with adjusting screws fitting a groove in the sliding cone. By a twist of the handle bar below, the cone is forced under the lever of the clutch, which tightly engages the hub of the driving-wheel, and the lap or slicer, as the case may be, is brought into immediate action; the reverse movement of course instantly disengages the clutch, and the lap or slicer become stationary. The photograph (Plate XVI.), which shows a portion of the main shaft, driving wheels and clutches, will serve to make this portion of the mechanism sufficiently clear.

Connection between the driving wheel and each spindle, by means of a leather cord, is easily effected, the latter passing directly from wheel to spindle with the aid of guide pulleys only, these being secured to the under surface of the table.

Provision was originally made for two speeds, the change being effected by means of split pulleys on the spindle, which can easily be removed if required: but this is seldom necessary. A uniform speed of about 980 revolutions per minute has been found in every way satisfactory.

An extremely useful adjunct to the rock slicer is to be found in the small emery grinder attached to the same bench (seen to the left of Plate XV.) and driven in the same manner. It is speeded up to 2000 (or more) revolutions per minute, and has been found most convenient for a variety of work for which the larger machine is not so well adapted. It may be provided with various grinding and cutting wheels as well as polishers and brushes, which fit it for use upon fossils, and the grinding and polishing of small mineral and other specimens. This is an addition to its varied usefulness in the workroom generally.

4.—Method of Slicing, Grinding and Mounting Rock Sections.

It is only by adopting and pursuing a methodical and co-ordinated series of operations that the full value of a machine similar to the one just outlined is fully secured. To this end I have adopted a system of working, the main features of which are embodied in the following brief summary of its salient points:—

A. *Charging the Slicers, Etc.* This is invariably done with diamond powder, which it pays to crush, and sift from time to time during the operation. The sifting is easily done with the aid of several bits of glass tube about 1in. long and ¾in. wide, to one end of which, after grinding level, a bit of very fine bolting silk has been cemented. A slicer charged with properly graded diamond powder cuts faster and cuts longer than would be the case if the diamond were only ground to an almost impalpable powder in oil, as is frequently done: the former method is more effective as well as more economical.

Every slicer should be made to run "dead" true, and should be maintained in that condition. The greater the speed at which it is run, the more important it becomes that it should run truly. A slicer is always ineffective in proportion to its eccentricity. Too often the slicer is made to cut as long as it will cut; this is unsound, both in theory and practice.

With regard to charging a slicer, I find a chilled steel roller by far the most effective instrument for this purpose. It is better than any glass or agate implement; and, if properly made, is almost everlasting.

I have tried notching the slicers and charging the notches; it takes a long time to do this well—and it must be well done, or not at all. I was certainly rewarded with a slicer which cut well for a long time. Usually, however, I find a slicer charged in the ordinary way, that is by pressure of the diamond powder into the smoothly turned edge of the soft iron slicer, gives a very satisfactory return for the small amount of time and trouble it requires to prepare. A hundred sections, each of which involves two cuts, at a cost of little more than a shilling, leaves nothing to complain of in the matter of expense. In slicing I use kerosene for lubrication, that is, if the rocks are compact and hard; for such rocks it is more effective than a soap emulsion, which of course must be used for soft and porous rocks. Any good soap makes an effective lubricant if properly dissolved. It need not be castile soap, which, like many other things, is not always what it is claimed to be.

B. *Grinding Powders.*—For this purpose only the finest graded carborundum is used. I also regrade what is ordinarily sold as graded material by the manufacturer. For example, FFF grade of the Niagara Falls Coy. can well be further separated into two or three grades. The coarsest of these is used upon the finest of the two machine laps; the remaining finer grades are used for finishing purposes by hand.

For the coarse lap, I find a fine but well graded powder is more effective than one that is coarse; indeed, the latter is simply thrown off a rapidly revolving lap. Two hundred and twenty grade carborundum is the coarsest I use for rough work. Ordinarily the series of laps comprises one coarse, one fine and one finishing—lap of slate for hand use only.

C. *Canada Balsam and Mounting Methods.*—Many people fail in their first attempts to cut and prepare sections satisfactorily, not through lack of perseverance or skill, but because they do not carefully prepare their balsamed slips beforehand. Good clean natural Canada balsam alone, if carefully prepared, will hold almost any rock securely to the end of the process of its preparation. The tenacity and range of hardness of the balsam may, however, be extended if a small quantity, not more than 1 to 3 per cent., of some clear and colourless organic oil is added to it. Poppy oil, Castor oil, Clove oil—even Linseed oil—are all suitable if used in the right proportions, and here experience alone is the best guide. Those who have not tried the addition of one of these oils, or something similar, will appreciate the improvement effected by them, if the addition is judiciously made.

One should not prepare too many balsamed slips at once, as they continue to dry slowly if not used, and eventually become too brittle. As to mounting, the specimen should be attached, in the first instance, to the slip upon which it is to remain. Transference to another slip is obsolete and unnecessary. It did well for thick sections, which were formerly much more common than they are, or should be, to-day. Again, the section and slip should not be flooded with balsam when about to attach the cover, for, besides making a sticky and unsightly mess, it is both wasteful and unnecessary. Prolonged heating of slip and section is not advisable, when one is mounting, with the object of driving out all the solvent from the balsam. The chances are, when this is attempted, that the section will be disturbed or float, and will tend to break up when putting down the cover, besides raising a crop of bubbles, which are very difficult to remove. It is a wiser and safer course to use no more balsam, and to apply no more heat than is necessary to bring the cover into close and uniform relationship with the whole of the section. An oven with a water jacket, maintained at about 40 deg. Cent., will, in from three to five days, complete the drying with perfect safety.

So much for what is general and more or less applicable to almost any successful process for the preparation and mounting of rock sections.

I will now briefly outline the process adopted with a collection of, say, 20 numbered rock specimens, which are ready for slicing. It is to be noted that I seldom prepare sections from detached slices, as these involve two parallel cuts and much subsequent grinding. It is twice as economical, both as to time and material, to slice off the rock close to the mounting slip, as by this method the smallest possible amount of material remains to be ground away. Two dozen 3 x 1 inch slips are cleaned and placed, the whole upon white blotting paper, spread on a sheet of asbestos, or a metal plate; this is laid upon a well filled sand bath, supported on a tripod over a bunsen flame. The heat from the latter is so regulated as not to discolour or char the paper below the slips. Each slip is now balsamed, using no more than experience has shown to be necessary for sections about one inch in diameter. While the balsam is "cooking," the specimens are successively clamped in the large specimen holder of the slicing machine, and a piece, large enough for a section, is sliced away; the whole 20 being thus treated. Meantime, the balsamed slips will have become sufficiently hardened. Each slip should be separately tested, when cool, with forceps or knife; the hardened balsam should indent with moderate pressure without splintering.

The sliced face of each specimen is now, for a few seconds, held upon the finest revolving lap, which is fed with F.F. carborundum, and moistened with water containing about 1/5th of its volume of Glycerine, which maintains a rapidly revolving disc sufficiently moist, without excess, for a long time. Each specimen requires only a brief treatment, and if the lap is in first class order no further preparation should be required. Usually, however, it is safer to give each specimen a few sweeps by hand, upon a slate or glass lap, the surface of which should be accurately true or flat. After washing and drying, the specimens are ready for attachment to the balsamed slips. This is done by heating them sufficiently to occasion discomfort when held against the hand for a few seconds; the slip being correspondingly heated, the specimen is pressed home on the slip, taking care to exclude all air bubbles. As each slide is dealt with it is placed on a second plate of glass ($3\frac{1}{2}$ x $1\frac{1}{2}$ in. x 5/16th in. thick, the blocks being strictly uniform), and heated to melt the beeswax, which is used to hold the slip in position during its subsequent treatment. After the entire series has thus been treated and allowed to cool, each glass plate or block in turn is clamped in the special holder, and the slicer passed through the rock close to the glass of the mounting slip. With everything in good order, this may be done to within .5 mm.; the thickness being regulated by means of two strips of thin sheet iron, held in position on the slip while the cut is being started.

The series having been sliced, each section is ground to within .1 mm. on the coarse grinding lap, using F carborundum, or certainly not a coarser grade than 220. After washing, the grinding is completed on the finest revolving lap, and if the latter is true and the operator experienced, scarcely any further grinding will be required. With a sufficiently finely graded powder, there should be no scoring or scratches; the latter, if present, being due to fragments of too coarse a powder, or to its use in too limited a quantity, thus allowing the specimen to come in contact with the metal of the lap. As a rule, and for safety, it is wiser to give the last touches by hand upon a suitable lap of slate or glass, using only the finest washed powder.

The whole process is not so long, or so complicated as any description must necessarily seem to imply. With the aid of the machine described, and given balsamed slides in readiness, I find it possible to complete single slides in 10 to 15 minutes; the finished section, in area, uniformity and thinness, leaving little to be desired. Furthermore, with a series of rocks—and it is usual to treat a number together—there is a corresponding gain in time, throughout the several operations. Naturally too, and perhaps more particularly with the type of machine just described, individual experience, dexterity of manipulation and judgment, are material factors affecting the final result, both as to time and quality of work. Compared with the older type of machine, both hand and treadle, there can be no question as to the net gain, in time and labour, both of which are important. There is, too, I think, an equivalent improvement in the average quality of the finished product. On these grounds I hope the publication of this brief description will prove useful to all who are interested in the preparation of rock sections.

EXPLANATION OF PLATES XIV.-XVII.

Plate XIV.

New Rock-Slicing Machine, Melbourne University. Side view, showing slicing disc and grinding laps, and the supporting rods for the various clamps and specimen holders. The levers which operate the driving mechanism can be seen above and somewhat behind the spindles. The guard trays have been removed, so as to show the several parts of the machine more clearly. The lathe in the foreground is independent of the rock machine.

Plate XV.

New Rock-Slicing Machine, Melbourne University. Top view or photograph in plan serving to show the machine in working order. To the right of the view the slicer and one clamp are seen in position for slicing. A second clamp, for holding massive rocks, is shown on the extreme right; while the goniometer as adjusted for the slicer is seen in the right front corner of the guard tray. The two grinding laps, with supports and clamp adjustments for specimens, follow in order to the left of the slicer. Ordinarily, in the preparation of rock sections, the clamps above the grinding laps are not required; but in all operations involving precision their use is indispensable. The emery wheel and polisher referred to in the paper are situated on the extreme left of the table. A graduated 60 inch scale, the divisions on which are unfortunately not reproduced, lies along the front of the guard trays.

Plate XVI.

New Rock-Slicing Machine, Melbourne University. Driving mechanism in detail. The usual fast and loose pulley driven by the motor are seen upon the main shaft on the left of the photograph. To the right of these, the shaft passes successively through each driving pulley, which, in turn, connects with the machine below by means of a leather band. The pulleys, ordinarily stationary with the shaft running through them, are brought into action by the lever which forces the cone on the left under the lever of the clutch attached to the hub of each pulley.

Plate XVII.

New Rock Slicing Machine, Melbourne University. Fig. 1, Arrangement for serial section cutting. Fig. 2, Gonimeter attachment in position for grinding facets, etc. In Fig. 1, in addition to the usual clamp, which swings radially over the grinding lap, a graduated disc is shown. This disc is keyed to